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Physics 20 ■ 30

Program of Studies

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for the 1993–1994 school year.

Physics 30 is in field validation
for the 1993–1994 school year.



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PHYSICS 20–30

A. PROGRAM RATIONALE AND PHILOSOPHY

Physics is the study of matter and energy and their interactions. Through the study of physics, the learners are given an opportunity to explore and understand the natural world and to become aware of the profound influence of physics in their lives. Meaningful learning is facilitated by relating the study of physics to what the learners already know, deem personally useful and consider relevant. Learning proceeds best when it originates from a base of concrete experiences presenting an authentic view of science in the context of physics. In Physics 20–30, students learn physics in relevant contexts and engage in meaningful activities. This facilitates the transfer of knowledge to new contexts. Students are encouraged to participate in lifelong learning about physics and to appreciate physics as a scientific endeavour with practical impact on their own lives and on society as a whole.

Physics, as with all sciences, is an experimental discipline requiring creativity and imagination. Methods of inquiry characterize its study. In Physics 20–30, students further develop their ability to ask questions, investigate and experiment; to gather, analyze and assess scientific information; and to test scientific laws and principles and their applications. In the process, students exercise their creativity and develop critical thinking skills. Through experimentation, problem-solving activities and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The Physics 20–30 program places students at the centre. Students are active learners and will assume increased responsibility for their learning as they work through the program. A thorough study of physics is required to give students an understanding of the discipline that encourages them to make appropriate applications of scientific concepts to their daily lives and prepares them for future studies in physics. Students are expected to participate actively in their own learning; teachers act as collaborators or guides. An emphasis on the key concepts and principles of physics provides students with a more unified view of the sciences and a greater awareness of the connections among them.

These science learnings will take varying amounts of time to acquire, depending on the individual learning styles and abilities of students. While each course is designed for approximately 125 hours, teachers are encouraged to modify the amount of instructional time to meet the individual needs of students. Some students will require more than 125 hours, while others will require less.

GOALS

The major goals of the Physics 20–30 program are:

- to develop in students an understanding of the big interconnecting ideas and principles

that transcend and unify the natural science disciplines

- to provide students with an enhanced understanding of the scientific world view, inquiry and enterprise
- to help students attain the level of scientific awareness essential for all citizens in a scientifically literate society
- to help students make informed decisions about further studies and careers in science
- to provide students with opportunities for acquiring attitudes, knowledge and skills that contribute to personal development.

Physics 20–30 is an academic program that helps students better understand and apply fundamental concepts and skills. The focus is on helping students understand the physics principles behind the natural events they experience and the technology they use in their daily lives. The program encourages enthusiasm for the scientific enterprise and develops positive attitudes about physics as an interesting human activity with personal meaning. It develops in students the attitudes, knowledge and skills to help them become capable of, and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities.

B. GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for specific learner expectations. The general learner expectations are developed through the study of individual units in Physics 20–30 and, though listed sequentially, are not meant to be developed sequentially or separately.

ATTITUDES

Students will be encouraged to develop:

- an enthusiasm for, and a continuing interest in, science
- the effective attributes of scientists at work; such as, respect for evidence, tolerance of uncertainty, intellectual honesty, creativity, perseverance, cooperation, curiosity and a desire to understand
- positive attitudes toward scientific skills involving mathematics, problem solving and process skills
- open-mindedness and respect for the points of view of others
- a sensitivity to the living and non-living environment
- an appreciation for the roles of science and technology in our understanding of the natural world.

KNOWLEDGE

Science Themes

Students will be expected to demonstrate an understanding of themes that transcend the discipline boundaries, and show the unity among the natural sciences, including:

- **Change:** how all natural entities are modified over time, how the

direction of change might be predicted and, in some instances, how change can be controlled

- **Diversity:** the array of living and non-living forms of matter and the procedures used to understand, classify and distinguish those forms on the basis of recurring patterns
- **Energy:** the capacity for doing work that drives much of what takes place in the Universe through its variety of interconvertible forms
- **Equilibrium:** the state in which opposing forces or processes balance in a static or dynamic way
- **Matter:** the constituent parts, and the variety of states of the material in the physical world
- **Systems:** the interrelated groups of things or events that can be defined by their boundaries and, in some instances, by their inputs and outputs.

SKILLS

Students will be expected to develop an ability to use thinking processes associated with the practice of science for understanding and exploring natural phenomena, problem solving and decision making. These processes involve many skills that are to be developed within the context of the program content.

The skills framework presented here assumes that thinking processes often begin with an unresolved problem or issue, or an unanswered question. The problem, issue or question is usually defined and hypotheses formulated before information gathering can begin. At certain points in the process, the information

needs to be organized and analyzed. Additional ideas may be generated—for example, by prediction or inference—and these new ideas, when incorporated into previous learning, can create a new knowledge structure. Eventually, an outcome, such as a solution, an answer or a decision is reached. Finally, criteria are established to judge ideas and information in order to assess both the problem-solving process and its outcomes.

The following skills are not intended to be developed sequentially or separately. Effective thinking appears to be non-linear and recursive. Students should be able to access skills and strategies flexibly; select and use a skill, process or technology that is appropriate to the task, and monitor, modify or replace it with a more effective strategy.

- Initiating and Planning

- identify and clearly state the problem or issue to be investigated
- differentiate between relevant and irrelevant data or information
- assemble and record background information
- identify all variables and controls
- identify materials and apparatus required
- formulate questions, hypotheses and/or predictions to guide research
- design and/or describe a plan for research, or to solve a problem
- prepare required observation charts or diagrams

- Collecting and Recording

- carry out the procedure and modify, if necessary
- organize and correctly use apparatus and materials to collect reliable experimental data
- accurately observe, gather and record data or information according to safety regulations; e.g., Workplace Hazardous Materials Information System (WHMIS), and environmental considerations

- Organizing and Communicating

- organize and present data (themes, groups, tables, graphs, flow charts and Venn diagrams) in a concise and effective form
- communicate data more effectively, using mathematical and statistical calculations, where necessary
- express measured and calculated quantities to the appropriate number of significant digits, using SI units for all quantities
- communicate findings of investigations in a clearly written report

- Analyzing

- analyze data or information for trends, patterns, relationships, reliability and accuracy
- identify and discuss sources of error and their affect on results
- identify assumptions, attributes, biases, claims or reasons
- identify main ideas

- Connecting, Synthesizing and Integrating

- predict from data or information
- formulate further testable hypotheses supported by the knowledge and understanding generated
- identify further problems or issues to be investigated
- identify alternatives for consideration
- propose and explain interpretations or conclusions
- develop theoretical explanations
- relate the data or information to laws, principles, models or theories identified in background information
- propose solutions to a problem being investigated
- summarize and communicate findings
- decide on a course of action

- Evaluating the Process or Outcomes

- establish criteria to judge data or information
- consider consequences and perspectives
- identify limitations of the data or information, and interpretations or

- conclusions, as a result of the experimental/research/project/design process or method used
- suggest alternatives and consider improvements to experimental technique and design
- evaluate and assess ideas, information and alternatives

- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

Further Reading

For a more detailed discussion on how to integrate thinking and research skills into the science classroom, refer to the Alberta Education publications: *Teaching Thinking: Enhancing Learning* (1990) and *Focus on Research: A Guide to Developing Students' Research Skills* (1990).

Further Reading

For further reading on integrating science, technology and society into the classroom, refer to the Alberta Education publication: *STS Science Education: Unifying the Goals of Science Education* (1990).

CONNECTIONS AMONG SCIENCE, TECHNOLOGY AND SOCIETY

Science, Technology and Society (STS)

Students will be expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationship of science, technology and society, including:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology

C. SPECIFIC LEARNER EXPECTATIONS

LEARNING CYCLE

The specific learner expectations consist of the attitudes, knowledge and skills that are to be addressed in Physics 20–30. The use of the learning cycle allows students to progress from:

- an introduction framing the lesson in an STS connection relevant to the lives of the learners, and makes connections between past and present learning experiences, as well as anticipates activities to focus students' thinking on the learning outcomes of the activity, to
- the experiential exploration of new content that provides students with a common base of experiences within which they identify and develop key concepts, processes and skills, through
- a hypothesis-building phase where concepts are developed to describe a particular aspect of their experiential exploration, and opportunities are provided to communicate their conceptual understanding, or demonstrate their skills or behaviours, to
- an elaboration phase that extends understanding of key concepts and allows further opportunities to practise desired skills and problem-solving strategies, to
- an application phase where the hypothesis, vocabulary and patterns previously developed are applied to new situations and related to key concepts and principles of science, to
- a final evaluation of the significance of the new learning in an STS context to assess their understanding and abilities, and provide opportunities for teachers to evaluate student progress toward achieving the educational objectives.

In physics, students examine phenomena in a variety of topics to show the relationships among the sciences. Wherever possible, examples

should be framed in the context of the learners' own experiences to enable them to make the connections between scientific knowledge and the society around them, the technology that societies have developed, and the nature of science itself.

PROGRAM OVERVIEW

The Physics 20–30 program emphasizes the science themes: *change, diversity, energy, equilibrium, matter* and *systems*, as they relate to physics. These themes provide a means of showing the connections between the units of study in both courses of the program, and provide a framework for teachers to show students how individual sections of the program relate to the big ideas of science.

In addition to developing a solid understanding of the fundamental science concepts and principles, Physics 20–30 has the goal of educating students about the nature of science and technology, and the interaction between physics and technology. Students must be aware of the tremendous impact of physics and associated technology on society, but at the same time they must be aware of the roles and limitations of the physical sciences, science in general, and of technology in problem solving in a societal context.

PHYSICS 20

Energy is the science theme common to all units in Physics 20, with *change* and *matter* playing a subordinate role. *Energy* in its many forms causes *change* and determines the kind of *change matter* undergoes.

Physics 20 consists of five units of study:

- Unit 1: Kinematics and Dynamics
- Unit 2: Circular Motion and Gravitation
- Unit 3: Mechanical Waves
- Unit 4: Light
- Unit 5: Radioactivity.

An examination of motion and the causes of motion emphasizes the science theme of *change* in Unit 1. In Unit 2, the principles of motion are extended to circular motion, and lead into an investigation of gravitation. Unit 3 considers the transfer of *energy* by means of mechanical waves, and the characteristics of waves are studied in the context of sound. Unit 4 focuses on the nature of light, a visible form of *energy*. In Unit 5, a restricted study of the structure and radioactive nature of *matter* is conducted.

PHYSICS 30

The diversity of *matter* and *energy* are the predominant themes of the Physics 30 course.

The major concepts allow connections to be drawn among the five units for the course and among all ten units in the two courses in the program.

Physics 30 consists of five units of study:

- Unit 1: Conservation Laws
- Unit 2: Electric Forces and Fields
- Unit 3: Magnetic Forces and Fields
- Unit 4: Nature of the Atom
- Unit 5: Waves and Particles.

In Unit 1, students emphasize the science theme of *equilibrium*, as exemplified by the fundamental phenomenon of conservation in the physical universe. In Unit 2, the electrical nature of *matter* is examined. Unit 3 investigates the magnetic nature of *matter*, and electromagnetic interactions and technological applications. In Unit 4, the use of models, to interpret observed phenomena and develop scientific theories, is illustrated in the study of the nature of the atom. Unit 5 investigates the wave-particle duality in nature, and serves to unify the program, as many of the concepts previously studied are used in the explanations of this phenomenon.

PHYSICS 20

UNIT 1 KINEMATICS AND DYNAMICS

OVERVIEW

Science Themes: *Change and Energy*

In Unit 1, students investigate *change* in position and velocity of objects and *systems* in a study of kinematics. The investigation of dynamic phenomena demonstrates that a *change in energy* is the manifestation of the effect of forces on the motion of objects and *systems*.

This unit extends the study of motion first introduced in Science 7, Unit 3: Force and Motion, and further developed in Science 10, Unit 4: Energy and Change, to a formal study of uniform motion, uniform accelerated motion, Newton's Laws of Motion, and concludes with a formal introduction to mechanical energy, work and power. This provides students with a foundation for further study of mechanics in subsequent units and physics courses.

The three major concepts developed in this unit are:

- *change* in the position and velocity of objects and *systems* can be described graphically and/or mathematically
- the concepts of dynamics explicitly relate forces to their effect on *change* in motion
- mechanical work results in a transfer of *energy*.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities
- collecting, organizing, communicating and analyzing data from physical interactions

- relating the data to the laws and principles of kinematics and dynamics.

The STS connections in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying motion, energy, work and power
- accept uncertainty in the descriptions and explanations of motion in the physical world
- be open-minded in evaluating potential applications of mechanical principles to new technology
- appreciate the role the principles of mechanics play in our everyday world
- appreciate the need for accurate and honest communication of all evidence gathered in the course of an investigation related to mechanical principles
- appreciate the need for empirical evidence in interpreting observed mechanical phenomena
- appreciate the restricted nature of evidence when interpreting the results of physical interactions.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. Change in the position and velocity of objects and systems can be described graphically and/or mathematically.
 - the motion of objects and systems can be described in terms of displacement, time, velocity and acceleration, by extending from Science 10, Unit 4, the principles of one-dimensional motion, and by:
 - defining, operationally, and comparing and contrasting scalar and vector quantities
 - defining velocity as a change in displacement during a time interval
 - defining acceleration as a change in velocity during a time interval
 - comparing and contrasting uniform and non-uniform linear motion, uniform and non-uniform acceleration, average and instantaneous velocity
 - explaining uniform motion and uniformly accelerated motion, using position-time, velocity-time and acceleration-time graphs
 - applying the concepts of slope and area under the curve to determine velocity, displacement and acceleration from position-time and velocity-time graphs
 - determining the resultant displacement and velocity in two dimensions, graphically and/or mathematically, using the concept of vector components addition
 - explaining the uniform motion of objects, using algebraic and/or graphical methods, from verbal or written descriptions and/or mathematical data
 - explaining, quantitatively, two-dimensional motion, in horizontal or vertical planes, using vector quantities
 - explaining, quantitatively, the motion of one object relative to another object, using displacement and velocity vectors
 - using the delta notation correctly when describing change in quantities★
 - using unit analysis to check the results of mathematical solutions.★

★ To be developed throughout the course.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- performing experiments to demonstrate the relationships among acceleration, displacement, velocity and time, using interval timers to gather the necessary data
- inferring from a graphical analysis of empirical data the mathematical relationship among acceleration, displacement, velocity and time for uniformly accelerated motion
- analyzing empirical data graphically, using line-of-best-fit to discover mathematical relationships
- performing experiments to determine the local value of the acceleration due to gravity.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- evaluating the design of structures and devices in terms of kinematic principles; e.g., roadway approach and exit ramps, airport runways, carnival rides
- analyzing the use of kinematic concepts in the synchronization of traffic lights
- investigating and reporting on how the principles of kinematics are used in traffic accident investigations.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

2. The concepts of dynamics explicitly relate forces to their effect on change in motion.

- changes in motion are the result of unbalanced forces, by recalling from Science 7, Unit 3, the notions of force, inertia and friction, and by:
 - comparing and contrasting among mass, volume and weight
 - explaining how a force effects a change in motion
 - applying Newton's first law of motion to explain an object's state of rest or uniform motion
 - applying Newton's second law of motion and using it to relate force, mass and acceleration
 - relating Newton's third law of motion to interaction between two objects, recognizing that the two forces, equal in magnitude and opposite in direction, act on different bodies
 - determining, quantitatively, the net or resultant force acting on an object, using vector components addition graphically and/or mathematically
 - applying Newton's laws of motion to solve, algebraically, linear motion problems in horizontal, vertical and inclined planes, near the surface of Earth (whenever friction is included, only the resistive effect of the force of friction is considered)
 - solving projectile motion problems near the surface of the Earth, ignoring air resistance.

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- performing experiments to determine the relationships among acceleration, force and mass, using interval timers to gather the necessary data
- using free-body diagrams in organizing and communicating the solution of dynamics problems.

STS CONNECTIONS

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- explaining the movement of passengers in a vehicle changing speed and/or direction in terms of the law of inertia
- assessing the role the principles of inertia and acceleration play in the design and use of injury prevention devices in cars and sports; e.g., air bags, child restraint systems, running shoes, helmets
- evaluating the role of the principles of mechanics in establishing legal restrictions, such as seat belts and speed limits.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

3. Mechanical work results in a transfer of energy.
- mechanical energy interactions involve changes in kinetic and/or potential energy, by extending the mechanical energy concepts studied in Science 10, Unit 4, and by:
 - defining mechanical work as a measure of the energy transferred
 - analyzing, quantitatively, mechanical energy transformations, using the concept of conservation of energy.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- performing experiments investigating the relationships among mechanical energy, work and power
- illustrating the relationships among mechanical energy, work and power, using empirical data and/or algorithms.

- evaluating the design of energy transfer devices in terms of the relationships among mechanical energy, work and power; e.g., simple household tools, such as mechanical can openers, bottle openers, pliers, and/or transportation devices, such as elevators, escalators, ski lifts
- investigating and reporting on careers that require an understanding and application of kinematics and dynamics.

UNIT 2 CIRCULAR MOTION AND GRAVITATION

OVERVIEW

Science Themes: *Change, Energy and Systems*

In Unit 2, students investigate *change* in motion and position of objects, and the dynamic *equilibrium* of planetary systems, in a study of circular motion and gravitation. Uniform circular motion is seen as an example of conservation of *energy*.

This unit extends the study of kinematics and dynamics in Unit 1 to uniform circular motion, an introduction to periodic motion. Two-dimensional vectors and Newton's laws are used to analyze and explain circular motion with uniform orbital speed. The concept of "field" is introduced to explain gravitational effects, and the role that the physical principles of circular motion had in the development of Newton's universal law of gravitation is examined. Unit 2 provides students with a foundation for further study of mechanics and fields in subsequent units and physics courses.

The two **major concepts** developed in this unit are:

- the principles of uniform circular motion explain common examples of motion
- gravitational effects extend throughout the universe.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities
- collecting, organizing, communicating and analyzing data from physical interactions
- relating the data to the principles of uniform circular motion and gravitation.

The STS connections in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying motion and gravitational effects
- appreciate the fundamental role the principles of circular motion have in explaining observed artificial and natural phenomena
- appreciate the contribution made by Kepler, Newton and Cavendish to the development of Newton's Universal Law of Gravitation
- accept uncertainty in the descriptions and explanations of circular motion and gravitation in the physical world
- be open-minded in evaluating potential applications of the principles of circular motion and gravitation to new technology
- appreciate the role the principles of circular motion and gravitation play in our everyday world.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. The principles of uniform circular motion explain common examples of motion.
 - uniform circular motion requires a net force of constant magnitude, by:
 - describing uniform circular motion as a special case of two-dimensional motion
 - describing centripetal force as having one of several sources; e.g., gravitation, friction, electrostatics
 - applying, quantitatively, the centripetal force and acceleration equation to uniform circular motion
 - explaining the relationship between the concepts of Newton's laws of motion and circular motion
 - solving, quantitatively, circular motion problems, using algebraic and/or graphical vector analysis
 - explaining, quantitatively, circular motion, using the relationships among speed, frequency and period
 - analyzing, quantitatively, the motion of objects moving with constant speed in horizontal and/or vertical circles near the surface of the Earth.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- performing experiments to determine the relationship between the centripetal force and frequency, mass, speed and path radius of a revolving object.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- analyzing the principles of a centrifuge and its applications in industry and research
- analyzing the motion of a car moving through a curve with constant speed, in terms of the principles of circular motion, friction and road banking
- analyzing the motion of carnival rides and playground equipment moving in horizontal or vertical circles; e.g., roller coaster, merry-go-round
- analyzing, qualitatively, the function of a potter's wheel in terms of the principles of circular motion.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

2. Gravitational effects extend throughout the Universe.

- gravity is a universal effect, by:
 - explaining, qualitatively, how the principles of circular motion and Kepler's laws were used in the development of Newton's universal law of gravitation
 - explaining, qualitatively, the principles pertinent to the Cavendish experiment used to determine the gravitational constant, G
 - relating the universal gravitational constant to the local value of the acceleration due to gravity
 - predicting, quantitatively, changes in weight objects experience on different planets
 - defining "field" as a concept explaining action at a distance, and applying it to describing gravitational effects
 - applying, quantitatively, Newton's universal law of gravitation to explain planetary and satellite motion, using the circular motion approximation
 - predicting the mass of a planet with a satellite, using the principles of circular motion
 - explaining, qualitatively, the shape of our solar system, and that of galaxies, in terms of the principles of circular motion and gravitation.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- linking centripetal force to the gravitational force in planetary and satellite motion problems.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- discussing the potential applications of “microgravity” simulations
- evaluating the technological advantages of “microgravity” conditions for research and manufacturing, etc.
- examining the role of the principles of circular motion and gravitation in making geosynchronous satellites possible, and the applications of such satellites
- explaining the scientific and technological principles involved in designing and building a rotating space station
- evaluating the impact that living on a space station has on the quality of life
- assessing, objectively, the desirability of designing and building a space station
- evaluating the significance of planets appearing only just above the horizon and stars being observed overhead.

UNIT 3 MECHANICAL WAVES

OVERVIEW

Science Themes: *Energy and Matter*

In Unit 3, students investigate the transmission of *energy* through *matter* by means of mechanical waves.

This unit uses a brief introduction to simple harmonic motion as a bridge from circular periodic motion to linear oscillation. The concepts of motion and *energy* are extended to the study of mechanical wave characteristics and behaviour. Sound is used as an example of a mechanical wave and to enhance students' understanding of wave behaviour and characteristics. This unit serves as a link between the kinematics and dynamics units and the unit on light.

The two **major concepts** developed in this unit are:

- many vibrations are simple harmonic
- waves are a means of transmitting *energy*.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities
- collecting, organizing and communicating data from observations of mechanical wave phenomena
- predicting mechanical wave behaviour, from data or information.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the use of technology to solve practical problems

- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying wave behaviour and characteristics
- appreciate the fundamental role the principles of mechanical waves have in explaining observed artificial and natural phenomena
- accept uncertainty in the descriptions and explanations of wave phenomena in the physical world
- be open-minded in evaluating potential applications of mechanical wave principles to new technology
- appreciate the role the principles of mechanical waves play in our everyday world.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. Many vibrations are simple harmonic.

- simple harmonic motion links uniform circular motion to the characteristics of mechanical waves, by:
 - defining simple harmonic motion as motion toward a fixed point, with an acceleration that is proportional to the displacement from the equilibrium position
 - explaining that an object moving in simple harmonic motion experiences a restoring force toward a fixed point that is proportional to the displacement from the equilibrium position
 - explaining, qualitatively, the relationships among displacement, acceleration, velocity and time, for simple harmonic motion
 - explaining the relationships among kinetic, potential and total mechanical energies of a mass executing simple harmonic motion, using simple mathematical methods.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- designing and performing an experiment to demonstrate that simple harmonic motion can be observed in objects within certain limits, and relate the frequency and period of the motion to physical characteristics of the system; e.g., a mass on a light vertical spring or a simple pendulum.

- analyzing, qualitatively, dampening forces in real-life examples of simple harmonic motion; e.g., springs in vehicle suspensions, pendulum clocks, metronomes.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

2. Waves are a means of transmitting energy.

- vibrations are the source of waves that are usually transmitted through a medium, by:
 - comparing and contrasting energy transmission by matter that moves and by waves that move
 - explaining the characteristics of waves in terms of the direction of vibration of the medium particles in relation to the direction of propagation of the disturbance
 - defining and using the terms wavelength, amplitude, transverse and longitudinal, in describing waves
 - explaining how a wave travels with a speed determined by the characteristics of the medium
 - relating the frequency of a wave to the period of the source, and the speed of propagation to the frequency and wavelength
 - calculating any variable and predicting the effects of changing one or a combination of variables on any one of the remaining variables, in the relationship $v = f\lambda$, given two of the three variables
 - explaining the behaviour of waves at medium boundaries; e.g., reflection and transmission at "open" and "closed" ends
 - predicting the resultant displacement when two waves interfere, and drawing a diagram of the resultant wave, using the principle of superposition
 - defining resonance, and giving examples of mechanical and/or acoustical resonance
 - explaining the Doppler effect on a stationary observer with a moving source, and a moving observer with a stationary source.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- determining the speed of a water wave in a ripple tank or a wave pulse travelling along a stretched spring, flexible coil or rope
- observing the phenomena of reflection, refraction, diffraction and interference of mechanical waves
- designing and performing experiments to measure the speed of sound in air, using resonance in an air column that is closed at one end
- observing the phenomenon of mechanical and/or acoustical resonance
- identifying the differences between sounds, such as loudness, pitch and quality
- predicting and verifying the conditions required for mechanical resonance to occur with coupled pendula.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- assessing the implications of resonance in the design of structures and devices with moving parts; e.g., cars, bridges, buildings
- investigating the application of acoustical phenomena in music, medical, industrial and research technology; e.g., sonar, ultrasound, sonography
- evaluating the application of air columns in pipe organs and wind and brass instruments
- assessing the impact of noise and sound in our daily lives; e.g., traffic, industrial, recreational
- evaluating the design of berms and their impact on the quality of life in terms of safety and noise reduction
- investigating and reporting on the use of radar in terms of the principles of wave behaviour and characteristics
- investigating the requirements and potential of careers involving sound.

UNIT 4 LIGHT

OVERVIEW

Science Themes: *Diversity* and *Energy*

In Unit 4, students emphasize *energy* and *diversity*, in a study of the nature and behaviour of light.

The students apply prior knowledge about the characteristics and behaviour of waves, in addition to the principles and methods of ray optics, to the phenomenon of light. The nature of science is particularly emphasized by the attention paid to the use of models in the development of a theory of light. This unit provides students with a foundation for the study of electromagnetic radiation and the photon model of light in Physics 30.

The two major concepts developed in this unit are:

- geometric optics is one model used to explain the nature and behaviour of light
- the wave model of light improves our understanding of the behaviour of light.

In this unit, *students will* develop an ability to use the skills and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities
- collecting, organizing, communicating and analyzing data from observations of light phenomena
- relating the data to the behaviour and characteristics of light, identifying the limits of the data or information obtained.

The STS connections in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted

- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitation of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- appreciate that models are modified, as new and/or conflicting evidence is presented
- appreciate the need for computational competence in quantifying the behaviour of light
- appreciate the fundamental roles of models in explaining observed natural phenomena
- accept uncertainty in the descriptions and explanations of the behaviour and nature of light
- be objective in evaluating potential applications of the principles of the nature of light to new technology
- appreciate the role the principles of the nature and behaviour of light play in our everyday world.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. Geometric optics is one model used to explain the nature and behaviour of light.

- geometric optics can be used to explain observed phenomena of light, by:
 - explaining and citing evidence for the linear propagation of light
 - explaining a method of measuring the speed of light
 - calculating “c”, given experimental data of various methods employed to measure the speed of light
 - defining a ray as a straight line representing the rectilinear propagation of light
 - explaining, using ray diagrams, the phenomena of reflection and refraction at plane and uniformly curved surfaces and dispersion
 - stating and using Snell’s law in the form of $n_1 \sin \theta_1 = n_2 \sin \theta_2$
 - deriving the curved mirror equation from empirical data
 - solving reflection and refraction problems, using algebraic, trigonometric and graphical methods
 - analyzing simple optical systems, consisting of no more than two lenses or one mirror and one lens, using algebraic and/or graphical methods.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- designing and performing an experiment demonstrating that light travels in a straight line
- performing experiments demonstrating reflection and refraction at plane and uniformly curved surfaces
- deriving the mathematical representations of the laws of reflection and refraction, from the data obtained from these experiments
- performing an experiment to determine the index of refraction of several different substances, and predicting the conditions required for total internal reflection to occur.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- assessing the influence of available technology on the experimental designs used by Galileo, Roemer, Huygens, Fizeau, Foucault, Michelson and contemporary experimenters, to measure the speed of light
- assessing the effect of light on living organisms; e.g., growth, vision
- evaluating technological and biological applications of linear propagation, reflection and refraction of light; e.g., binoculars, eyeglasses, design of greenhouses, solar collectors
- explaining the application of the phenomenon of total internal reflection in technological devices; e.g., fibre optics in communication, medicine, research
- investigating the requirements and potential of careers involving optics.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

2. The wave model of light improves our understanding of the behaviour of light.

- wave optics can explain light phenomena that geometric optics cannot, by recalling from Unit 3, the behaviour of waves during reflection, refraction and interference, and by:
 - comparing and contrasting the explanations of reflection and refraction by the particle theory and by the wave theory of light
 - explaining, using the wave theory of light, the phenomena of reflection and refraction
 - explaining why geometric optics fail to adequately account for the phenomena of diffraction, interference and polarization
 - explaining, qualitatively and quantitatively, interference and diffraction, using the wave model of light
 - explaining how the results of Young's double slit experiment support the wave theory of light
 - solving, quantitatively, double slit problems, using $\lambda = xd/nl$
 - solving diffraction grating problems, using $\lambda = d\sin\theta/n$
 - explaining, qualitatively, polarization in terms of the wave model of light
 - demonstrating how Snell's law in the form $n_2/n_1 = v_1/v_2 = \lambda_1/\lambda_2$ offers support for the wave model of light.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- predicting the conditions required for diffraction to be observed
- performing an experiment to determine the wavelength of a light source in air or a liquid, using a "Young's double slit" apparatus or a diffraction grating
- predicting, and performing an experiment to verify the effects on an interference pattern due to changes in any one or more of the following variables: wavelength, slit separation or screen distance.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- investigating and reporting on Newton's influence on the development of a model for the theory of light
- identifying and explaining, qualitatively, Poisson's spot as an example wherein a model predicted new light phenomena
- analyzing, qualitatively, the structure and function of polarizing filters in everyday life; e.g., sunglasses, photography
- investigating research into the role of the principle of polarization in nature; e.g., bees.

UNIT 5 RADIOACTIVITY

OVERVIEW

Science Themes: *Change, Energy and Matter*

In Unit 5, students investigate *change, energy and matter* in a study of radioactivity.

A qualitative study of the structure of the nucleus, the primary forces in nature, radioactivity and nuclear *energy* introduce the student to topics of considerable scientific and social importance in our society. This unit provides students with a foundation for the study of related topics in Physics 30, and should also equip students with some basic knowledge required by citizens who will be making decisions about the future role of nuclear technology.

The three **major concepts** developed in this unit are:

- the composition of the nucleus provides a key to the radioactive nature of an atom
- radioactivity is a natural phenomenon
- nuclear fission and fusion as sources of *energy*.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- organizing, communicating and analyzing data
- predicting, using data from radioactive interactions.

The **STS connections** in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions

- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- develop a sense of social concern over the reality that technological applications of radioactivity involve risks, which must be weighed against the benefits of nuclear technology to society
- develop curiosity about the new knowledge provided by ongoing research in nuclear physics
- appreciate that scientific knowledge has a significant role to play in political decision making
- appreciate the need for empirical evidence in interpreting observed phenomena
- be open-minded in evaluating potential applications of the principles of nuclear physics to new technology
- appreciate the role the principles of radioactivity play in our everyday world.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. The composition of the nucleus provides a key to the radioactive nature of an atom.
 - the structure of the nucleus determines the properties of an atom, by extending from Science 10, Unit 3, the commonly held view of the structure of the atom, and by:
 - relating the size and mass of the nucleus to the size and mass of the atom
 - describing the nature and role of the nucleons
 - using the isotope notation to describe and identify common nuclear isotopes, and determine the number of each nucleon of an atom
 - explaining, qualitatively, the nature and role of primary forces in nature: gravitational, electromagnetic, strong and weak nuclear
2. Radioactivity is a natural phenomenon.
 - radioactivity is linked to the structure and composition of the nucleus, by:
 - explaining the nature and behaviour of alpha, beta and gamma radiation
 - writing nuclear equations for alpha and beta decay
 - performing simple half-life calculations
 - predicting the particles emitted by a nucleus from the examination of a transmutation equation
 - explaining, qualitatively, how radiation is absorbed by matter, and compare and contrast the biological effects of different types of radiation.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- using library resources to research and report on selected scientists who contributed to our understanding of the structure of the nucleus

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- evaluating the role of conservation laws in the development of the theory of atomic structure
- assessing the value to society of nuclear and particle research

- inferring radiation properties from experimental data provided
- graphing data for radioactive decay and interpolating values for half-life
- interpreting some common nuclear decay chains.

- investigating and reporting on the work of Henri Becquerel, Marie and Pierre Curie, and/or Ernest Rutherford, with respect to radiation
- discussing the experimental designs used in the original identification of alpha, beta and gamma radiation
- evaluating methods and technologies used in detecting radioactive emissions
- evaluating the applications of radiation phenomena and technologies in research, medicine, agriculture, industry; e.g., isotope tracing, food irradiation, dating by isotopes
- assessing the risks and benefits of exposure to natural background radioactivity and artificially induced radioactivity; e.g., air travellers to cosmic radiation, dental X-rays.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

3. Nuclear fission and fusion as sources of energy.

- processes of nuclear fission and fusion are nature's most powerful energy sources, by recalling from Science 10, Unit 1, the source of all energy being the Sun, and the fusion reaction taking place in the Sun, and by:
- comparing and contrasting the fission and fusion reactions
- explaining, qualitatively, the importance of Einstein's concept of mass-energy equivalence
- explaining the importance of a chain reaction to nuclear reactions, identifying the process steps.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- performing a qualitative risks benefits analysis of a nuclear energy application.

- evaluating, qualitatively, the risks and benefits of using fission and/or fusion as commercial sources of energy
- analyzing the issues associated with disposing of the waste products from nuclear installations
- investigating the requirements and potential of careers involving nuclear physics.

PHYSICS 30

UNIT 1 CONSERVATION LAWS

OVERVIEW

Science Themes: *Energy and Equilibrium*

In Unit 1, students investigate *energy* and *equilibrium* in the physical world, in a study of the conservation principle as it applies to *energy* and *momentum*.

In this unit, the *energy* concepts from Science 10, Unit 4: Energy and Change, and Physics 20, Unit 1: Kinematics and Dynamics, are recalled and extended. The vector nature of momentum is explored through the algebraic and graphical solution of conservation of linear momentum problems. The principles learned are reinforced by analyzing common and practical physical interactions. This provides students with a foundation for further study of mechanics in subsequent units and physics courses.

The two **major concepts** developed in this unit are:

- conservation of *energy* in a closed *system* is a fundamental physical concept
- momentum is conserved when objects interact in a closed *system*.

In this unit, *students will* develop an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities
- collecting, organizing, communicating and analyzing data from physical interactions
- relating the data to the laws and principles of conservation of energy and momentum.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying conservation of energy and momentum
- appreciate the need for simplicity in scientific explanations of complex physical interactions and the role conservation laws play in many of these explanations
- be open-minded in evaluating potential applications of conservation principles to new technology
- appreciate the role the principles of conservation play in our everyday world
- appreciate the need for empirical evidence in interpreting observed conservation phenomena
- appreciate the restricted nature of evidence when interpreting the results of physical interactions
- accept uncertainty in the descriptions and explanations of conservation in the physical world
- appreciate the need for accurate and honest communication of all evidence gathered in the course of an investigation related to conservation principles.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. Conservation of energy in a closed system is a fundamental physical concept.
 - mechanical energy interactions involve changes in kinetic and potential energy, by extending the mechanical energy concepts studied in Physics 20, Unit 1, and by:
 - describing energy and mass as scalar quantities
 - defining mechanical energy as the sum of potential and kinetic energy
 - solving conservation problems, using algebraic and/or graphical analysis
 - analyzing and solving, quantitatively, kinematics and dynamics problems, using mechanical energy concepts by extending the problem-solving methods from Physics 20, Unit 1
2. Momentum is conserved when objects interact in a closed system.
 - conservation laws provide a simple means to explain interactions between objects, by:
 - describing momentum as a vector quantity
 - defining momentum as a quantity of motion equal to the product of the mass and the velocity of an object
 - relating a change in momentum of a particle of given mass to acceleration and time elapsed
 - relating Newton's laws of motion, quantitatively, to explain the concepts of impulse and a change in momentum
 - explaining, quantitatively, using vectors, that momentum appears to be conserved during one- and two-dimensional interactions in one plane between objects (the sine and cosine rules are not required)
 - defining, comparing and contrasting elastic and inelastic collisions, using quantitative examples
 - comparing and contrasting scalar and vector conservation laws.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- designing and performing experiments demonstrating the law of conservation of energy, and the relationship between mechanical potential and kinetic energy
- using free-body diagrams in organizing and communicating the solutions of conservation problems
- analyzing data graphically, using curve-straightening techniques, to infer mathematical relationships

- investigating and reporting the application of conservation principles in research and design

- performing and analyzing experiments demonstrating the conservation of momentum and the principle of impulse
- approximating, estimating and predicting results of interactions, based on an understanding of the conservation laws.

- assessing the role conservation laws and the principle of impulse play in the design and use of injury prevention devices in cars and sports; e.g., air bags, child restraint systems, running shoes, helmets
- analyzing how the need for decreasing momentum over a long period has influenced the design of ropes used in activities, such as "bunji" jumping and mountain climbing
- investigating and reporting on a technology developed to improve the efficiency of energy transfer
- investigating and reporting on a safety device that results in a cost saving to consumers and society.

UNIT 2 ELECTRIC FORCES AND FIELDS

OVERVIEW

Science Theme: *Diversity*

In Unit 2, the *diversity* of matter is highlighted as its electric nature is considered in the context of electrical interactions.

The students learn the principles of electrostatics and how to describe the interaction of electric charges mathematically from empirical data. The concept of field, introduced in Physics 20, Unit 2: Circular Motion and Gravitation, is applied to electrical phenomena. The concepts from Physics 20, Unit 1: Kinematics and Dynamics, are extended to charged particle dynamics. The unit concludes with the consideration of electric energy and simple DC circuits. This unit provides students with a foundation for further study of electrical principles in subsequent units and physics courses.

The four **major concepts** developed in this unit are:

- the concepts of electrostatics are used to explain the behaviour of electric charges at rest
- Coulomb's law relates electric charge to electric force
- electric field theory is a model used to explain how charges interact
- electric circuits facilitate the use of electric energy.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities
- collecting, organizing, communicating and analyzing data from electrical interactions
- relating the data to the laws and principles of electric forces and fields.

The STS connections in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying electrical interactions
- appreciate the need to follow safe practices when working with electricity
- foster a responsible attitude to environmental and social change as related to the use and production of electrical energy
- appreciate the restricted nature of evidence when interpreting the results of electrical interactions
- accept uncertainty in the descriptions and explanations of electrical phenomena in the physical world
- be open-minded in evaluating potential applications of electrical principles to new technology
- appreciate the role the principles of electricity play in our everyday world.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. The concepts of electrostatics are used to explain the behaviour of electric charges at rest.
 - the electrical model of matter is fundamental to the explanation of electrical interactions, by:
 - describing matter as containing discrete positive and negative particles
 - explaining electrical interactions in terms of the law of conservation of charge
 - explaining electrical interactions in terms of the law of electric charge (two types of charge; like charges repel, unlike charges attract)
 - comparing and contrasting the methods of transferring charge: conduction and induction
2. Coulomb's law relates electric charge to electric force.
 - Coulomb's law explains the relationships among force, charge and separating distance, by:
 - explaining, qualitatively, the principles pertinent to Coulomb's torsion balance experiment
 - explaining, quantitatively, using Coulomb's law and vectors, the electrostatic interaction between discrete point charges
 - comparing and contrasting the inverse square relationship as it is expressed by Coulomb's law and Newton's universal law of gravitation.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- performing an activity demonstrating the electrical nature of matter, using methods of electrification, and describing observations in terms of the laws of electrostatics
- using safe practices when conducting electrical experiments

- assessing how the principles of electrostatics are used in industry and technology; e.g., photocopiers, electrostatic air cleaners and precipitators, etc.
- investigating natural and artificial electrical discharge and the need for grounding

- performing an experiment demonstrating the relationships among magnitude of charge, electric force and distance
- inferring the mathematical relationship between force and charge, and separating distance from empirical evidence.

- evaluating the experimental designs used by Coulomb and Cavendish.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

3. Electric field theory is a model used to explain how charges interact.
 - the concept of field is applied to electric interactions, by extending from Physics 20, Unit 2, the definition of field, and by:
 - comparing and contrasting scalar and vector fields
 - comparing and contrasting forces and fields
 - explaining, quantitatively, using vector addition, electric fields in terms of intensity (strength) and direction relative to the source of the field
 - explaining, quantitatively, using vector addition, electric fields in terms of intensity (strength) and direction relative to the effect on an electric charge
 - predicting, using algebraic and/or graphical methods, the path followed by a moving electric charge in a uniform electric field, using kinematics and dynamics concepts
 - explaining electrical interactions, quantitatively, using the conservation laws (energy and charge).

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- plotting electric fields, using field lines, for fields induced by discrete point charges, combinations of discrete point charges and charged parallel plates (like and oppositely charged)
- linking centripetal force to the electric force in the motion of an electric charge following a curved path in an electric field.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- evaluating electric field theory as a model used to explain the behaviour of electric charges
- explaining, qualitatively, how sensitive components in a computer are protected from electric fields.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

4. Electric circuits facilitate the use of electric energy.

- Ohm's law and Kirchhoff's rules are fundamental to explaining simple electric circuits, by:
 - defining current, potential difference, resistance and power, using appropriate terminology
 - defining the ampere as a fundamental science unit, and relating the coulomb and volt to it
 - distinguishing between conventional and electron flow current
 - explaining Ohm's law as an empirical, rather than a theoretical, relationship
 - quantifying electrical energy and power dissipated in a resistor, using Ohm's law
 - explaining Kirchhoff's current and voltage rules as a logical consequence of the laws of conservation of energy and change
 - analyzing, quantitatively, simple series and parallel DC circuits in terms of the variables of potential difference, current and resistance, using Kirchhoff's rules and/or Ohm's law.

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- determining, from empirical and theoretical evidence, the relationships among electric energy/power, current, resistance and voltage
- performing an experiment to explain the relationships among current, voltage and resistance
- designing, analyzing and solving simple resistive DC circuits
- drawing diagrams of simple resistive DC circuits, using accepted symbols for circuit components
- designing and performing an experiment demonstrating the heating effect of electric energy.

STS CONNECTIONS

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- analyzing common technological applications of electricity in our lives; e.g., toasters, hair dryers, light fixtures
- comparing and contrasting electrical energy with other energy sources with respect to factors, such as cost, energy potential, risks and benefits to society, safety concerns
- analyzing the use of parallel and series networks in household circuits
- investigating the need for and the function of circuit breakers in household circuits
- analyzing the risks of electric shock
- investigating the requirements and potential of careers involving electricity.

UNIT 3 MAGNETIC FORCES AND FIELDS

OVERVIEW

Science Theme: *Diversity*

In Unit 3, the *diversity* of matter is highlighted as its magnetic nature is considered in the context of electric and magnetic interactions.

The concept of field, introduced in Physics 20, Unit 2: Circular Motion and Gravitation, is applied to magnetic phenomena. The concepts from Physics 20, Unit 1: Kinematics and Dynamics, are applied to charged particle dynamics in magnetic fields. The principles of electromagnetism are further applied to an investigation of the functioning of electric motors, generators and transformers. The unit concludes with the consideration of the characteristics of the electromagnetic spectrum. This unit provides students with a foundation for further study of electromagnetic principles in subsequent units and physics courses.

The three **major concepts** developed in this unit are:

- magnetic field theory is a model to describe magnetic behaviour
- electromagnetism pervades the universe
- electromagnetic radiation is a physical manifestation of the interaction of electricity and magnetism.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities
- collecting, organizing, communicating and analyzing data from electromagnetic interactions
- relating the data to the laws and principles of magnetic forces and fields.

The STS connections in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the need for computational competence in quantifying electromagnetic phenomena
- appreciate the parallelism in the characteristics of electrical, gravitational and magnetic phenomena
- appreciate the need to follow safe practices when working with electricity
- appreciate the restricted nature of evidence when interpreting the results of electromagnetic interactions
- accept uncertainty in the descriptions and explanations of electromagnetic phenomena in the physical world
- be open-minded in evaluating potential applications of electromagnetic principles to new technology
- appreciate the role the principles of electricity and magnetism play in our everyday world.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. Magnetic field theory is a model to describe magnetic behaviour.
 - field theory can be used to describe magnetic interactions, by:
 - explaining the source of magnetic characteristics of matter
 - comparing and contrasting the magnetic properties of Earth and artificial magnets
 - explaining magnetic interactions in terms of vector fields
 - comparing and contrasting gravitational, electric and magnetic fields in terms of their sources and directions.

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- plotting magnetic fields, using field lines to show the shape and orientation of the magnetic field of a variety of sources; e.g., Earth, electromagnets, permanent magnets (magnetic fields resulting from magnetic poles or current-carrying conductors).

STS CONNECTIONS

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- evaluating magnetic field theory as a model to describe and predict observations of magnetic behaviour
- discussing contemporary developments in the fields of electricity and magnetism, and their immediate and potential impact on our lives; e.g., superconductivity
- investigating and reporting the effects of magnetism on the behaviour of living organisms.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

2. Electromagnetism pervades the universe.

- magnetic fields and forces are described in relation to electric currents, by extending electromagnetic concepts from Science 9, Unit 4, and by:
 - demonstrating how the discoveries of Oersted and Faraday form the foundation of the theory relating electricity to magnetism
 - describing a moving charge as the source of a magnetic field, and predicting the orientation of the magnetic field from the direction of motion
 - predicting, quantitatively, how a uniform electric and/or magnetic field affects a moving electric charge, using the relationships among charge, motion and field direction
 - relating, and explaining qualitatively, the interaction between a magnetic field and a moving charge as to how a magnetic field affects a current-carrying conductor
 - predicting, quantitatively, the effect of an external magnetic field on a current-carrying conductor
 - describing the effects of moving a conductor in an external magnetic field, using the analogy of a moving charge in a magnetic field
 - predicting, quantitatively, the effects of a magnetic field on a moving conductor
 - explaining the relationship between, and calculating, the effective and maximum values of voltage and current in AC devices, given appropriate information
 - discussing, qualitatively, Lenz's law in terms of conservation of energy; describing, giving examples, situations where Lenz's law applies.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- designing, performing and analyzing experiments demonstrating magnetic field-current interactions
- predicting, using the LHR or RHR (hand rules), the relative directions of motion, force and field in electromagnetic devices
- linking centripetal force to the magnetic force in the motion of an electric charge following a curved path in a magnetic field
- predicting, quantitatively, and verifying, the effects of changing one, or a combination, of the variables in the relationship $N_p/N_s = V_p/V_s = I_s/I_p$.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- identifying and analyzing the application of electromagnetic interactions in several types of technology, given sufficient background information
- explaining, qualitatively, the design and function of AC and DC motors, generators, meters and other simple electromagnetic devices, using correct scientific terminology
- assessing the impact of the transformer and alternating current on the generation, transmission and use of electrical energy
- explaining one application that uses moving charged particles technology in terms of electromagnetic principles; e.g., cathode-ray tubes, particle accelerators, mass spectrometers
- evaluating, objectively, biomedical applications of electromagnetic technology; e.g., magnetic resonance imaging (MRI), positron emission tomography (PET), computerized axial tomography (CAT)
- evaluating the contributions of science, technology and mathematics to our cultural heritage
- analyzing the parallels among electrical, magnetic and gravitational phenomena
- evaluating the importance of the conservation laws in physical phenomena.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

3. Electromagnetic radiation is a physical manifestation of the interaction of electricity and magnetism.

- Maxwell's theory of electromagnetism expanded on Oersted's and Faraday's generalizations, by:
 - stating that all electromagnetic radiation is the result of accelerating electric charges, and demonstrates wavelike behaviour
 - comparing and contrasting the constituents of the electromagnetic spectrum on the basis of frequency, wavelength and energy
 - solving problems algebraically, using the relationship among speed, wavelength, frequency and/or distance, of electromagnetic waves
 - comparing and contrasting natural and technological processes by which the major constituents of the electromagnetic spectrum are produced
 - explaining, qualitatively, Maxwell's theory of electromagnetism
 - explaining the propagation of electromagnetic radiation in terms of perpendicular electric and magnetic fields, varying with time, travelling away from their source at the speed of light.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- performing experiments, and/or using simulations, demonstrating the wavelike behaviour of electromagnetic radiation
- predicting the conditions required for electromagnetic radiation emission.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- assessing the risks and benefits of the effects of electromagnetic radiation on living systems
- evaluating the contributions of technology that use different regions of the electromagnetic spectrum to advance our knowledge of the Universe
- analyzing the impact of electromagnetic technology on daily activities
- researching and reporting on the use of electromagnetic radiation technology in scientific fields, such as biology, chemistry, medicine, astronomy, etc.
- explaining how the propagation of electromagnetic radiation through a vacuum led to the inference that electromagnetic radiation must possess wave-particle duality
- evaluating the risks and benefits of applications of electromagnetic radiation in daily lives and clinical settings
- investigating the requirements and potential of careers involving electromagnetism.

UNIT 4 NATURE OF THE ATOM

OVERVIEW

Science Themes: *Diversity and Matter*

In Unit 4, students emphasize the science themes of *matter* and *diversity*, as the electric nature of *matter* is considered in the context of developing an atomic theory.

Building on previous learning from Science 10, Unit 3: Matter and Energy in Chemical Change, and Physics 20, Unit 5: Radioactivity, development of the Bohr model of the atom is studied. The concept of quantization used by Bohr provides a link to Unit 5 where the quantization of *energy* transfer is emphasized. The unit concludes with the consideration of the inadequacies of the Bohr model. This unit provides students with a foundation for further study in physics.

The four **major concepts** developed in this unit are:

- the atom has an electric nature
- the emission and absorption spectra of elements contributed to the development of an atomic model
- modern atomic theory began with the Rutherford–Bohr model of the atom
- the Bohr model proved to be an inadequate model of the atom.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- collecting, organizing, communicating and analyzing data from empirical and theoretical evidence
- relating the data to a theoretical model of the atom.

The **STS connections** in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the ways in which science advances technology and technology advances science
- the limitations of scientific knowledge and technology.

ATTITUDES

Students will be encouraged to:

- appreciate that models are modified as new and/or conflicting evidence is presented.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. The atom has an electrical nature.

- the discovery of the electron contributed to the formulation of atomic models, by:
 - explaining how the discovery of cathode rays contributed to the development of atomic models
 - explaining Thomson's experiment and the significance of the results
 - deriving the relationship $q/m = v/BR$, using circular motion and charged particles in electric and magnetic fields concepts
 - explaining Millikan's experiment and its significance relative to charge quantization
 - explaining the necessity for Planck to introduce the quantum of energy concept to explain black-body radiation adequately
 - defining the photon as a quantum of electromagnetic radiation
 - relating the electronvolt, as a unit of energy, to the joule

2. The emission and absorption spectra of elements contributed to the development of an atomic model.

- an indication of atomic structure was provided by the emission and absorption spectra of atoms, by:
 - stating that each element has a unique line spectrum, and comparing and contrasting the characteristics of continuous and line spectra
 - explaining, qualitatively, the conditions necessary to produce line emission and line absorption spectra
 - explaining the quantum implications of the line absorption and the line emission spectra, and determining any variable in the Balmer equation $1/\lambda = R_H (1/n_f^2 - 1/n_i^2)$.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- performing an experiment, or using simulations, to determine the charge to mass ratio of the electron
- determining, quantitatively, the mass of an electron and/or ion, given appropriate empirical data

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- analyzing how the identification of the electron and its characteristics is an example of the interaction of science and technology
- evaluating how, in the scientific process, discoveries are often missed by investigators failing to identify and/or correctly interpret evidence; e.g., X-rays

- observing representative line spectra of selected elements
- predicting the conditions necessary to produce and observe line emission and line absorption spectra.

- analyzing how Jakob Balmer developed an empirical relationship for the known lines of the hydrogen spectrum, which also predicted the existence of other lines and series of lines.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

3. Modern atomic theory began with the Rutherford-Bohr model of the atom.

- the Rutherford-Bohr model of the atom represents a synthesis of classical and quantum concepts, by:
 - explaining, qualitatively, the significance of the results of Rutherford's scattering experiment
 - describing Rutherford's model of the atom as a planetary model
 - explaining why Maxwell's theory of electromagnetism predicts the failure of a planetary model of the atom
 - explaining, qualitatively, Bohr's model for the hydrogen atom
 - explaining Bohr's concept of "stationary states" and its relationship to line spectra of atoms, and using the frequency/wavelength of an emitted photon to determine the energy difference between states
 - stating that the Bohr atom can be used to predict the ionization energy of hydrogen, and to calculate the allowed radii of the hydrogen atom
 - explaining the relationship between hydrogen's absorption spectrum and its energy levels.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- predicting the potential energy transitions in the hydrogen atom, using a labelled diagram showing the energy levels.

- evaluating the significance of predicted values for allowed radii and the electron energies for “stable states” agreeing with measured values
- analyzing the experimental design used by Franck and Hertz to confirm the existence of energy levels in atoms
- evaluating the implication of the Bohr model for the existence of matter waves
- investigating and reporting on the use of line spectra in the study of the Universe and the identification of substances.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

4. The Bohr model proved to be an inadequate model of the atom.

- the Bohr model offers a restricted explanation of the structure of the atom, by:
 - explaining that only the structure of the hydrogen atom can be predicted with any degree of certainty
 - stating that the Bohr model does not explain the effect electric and magnetic fields have on line spectra
 - recalling that the Bohr model does not reconcile Maxwell's electromagnetic theory predicting the collapse of a planetary atom
 - stating that the Bohr model does not explain the relative intensities of spectral lines
 - listing the successes of the Bohr model: it explained the line emission and absorption spectra; it introduced the concepts of electron shells and valence electrons.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- investigating, using library resources, the contributions made to the scientific enterprise by scientists; e.g. Rutherford, Bohr.

- evaluating an atomic theory on its explanatory and predictive powers
- investigating and reporting on the impact Bohr's postulates had on the scientific community.

UNIT 5 WAVES AND PARTICLES

OVERVIEW

Science Themes: *Energy and Matter*

In Unit 5, students explore wave-particle duality, emphasizing *matter* and *energy*.

The unit builds on learning in all previous units by considering the contribution to physical theories made by the explanation of the photoelectric effect, and the hypothesis that particles can exhibit a wave nature. The unit offers an opportunity to discuss the current directions followed by research in physics, and provides students with a foundation for further study in physics.

The two **major concepts** developed in this unit are:

- the photoelectric effect requires the adoption of the photon model of light
- wave-particle duality is a property of *matter*.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning activities
- collecting, organizing, communicating and analyzing data from empirical and theoretical evidence
- relating the data to the principles of the wave-particle duality of matter.

The **STS connections** in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- appreciate that models are modified as new and/or conflicting evidence is presented
- appreciate the role of mathematics in the contemporary view of our universe.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

1. The photoelectric effect requires the adoption of the photon model of light.

- the quantum concept was required to explain adequately some natural phenomena, by:
 - stating that Hertz discovered the photoelectric effect while investigating electromagnetic waves
 - explaining the photoelectric effect in terms of the intensity and wavelength of the incident light and surface material
 - assessing the assumptions made by Einstein in explaining the photoelectric effect
 - defining threshold frequency as the minimum frequency giving rise to the photoelectric effect, and work function as the energy binding an electron to a photoelectric surface
 - explaining the relationship between the kinetic energy of a photoelectron and stopping voltage
 - using Einstein's equation, quantitatively, to describe photoelectric emission
 - describing the photoelectric effect as a phenomenon that supports the notion of the wave-particle duality of electromagnetic radiation
 - explaining X-ray production as an inverse photoelectric effect, and predicting, quantitatively, the short wavelength limit of X-rays produced, given appropriate data.

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- performing an experiment demonstrating the photoelectric effect, and interpreting the data obtained
- predicting and verifying the effect that changing the intensity and/or frequency of the incident radiation or the material of the photocathode has on photoelectric emission.

STS CONNECTIONS

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- analyzing various applications of the photoelectric effect; e.g., automatic door openers, burglar alarms, light meters, smoke detectors
- discussing why the photoelectric effect cannot be explained, using the wave model of electromagnetic radiation
- identifying industrial and scientific uses of X-rays; e.g., X-ray examination of welds, crystal structure analysis
- investigating and reporting on the contributions made by scientists to the development of early quantum theory; e.g., Hertz, Planck, Einstein, Bohr.

MAJOR CONCEPTS

KNOWLEDGE

Students should be able to demonstrate an understanding that:

2. Wave-particle duality is a property of matter.

- wave-particle duality is not confined to electromagnetic radiation, by:
 - explaining, qualitatively, the Compton effect applying the laws of mechanics, conservation of momentum and energy to photons, as an example of duality
 - explaining the de Broglie hypothesis regarding the wave nature of matter
 - describing, qualitatively, empirical evidence that demonstrates the wave nature of particles; e.g., electron diffraction
 - describing the accepted model of the atom as a purely mathematical one, based on probability and waves
 - comparing and contrasting, qualitatively, the Rutherford, the Bohr and the quantum model of the atom.

SKILLS

STS CONNECTIONS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:

- using library resources, researching and reporting the contributions made to the scientific enterprise by scientists; e.g., Compton, de Broglie, Davisson, Germer.

Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:

- analyzing how quantum concepts led to technological advances that benefit society; e.g., semiconductors, electron microscopes, computers
- evaluating how quantum concepts have changed our understanding of the Universe
- discussing the probabilistic view of physical science held by most physicists.

D. BASIC LEARNING RESOURCES

Physics 20 and Physics 30

Martindale, David G., Robert W. Heath and Philip C. Eastman. *Fundamentals of Physics*. Combined edition. Toronto, ON: D. C. Heath Canada Ltd., 1992.

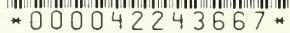
ISBN 0669953415

Zitzewitz, Paul W., Mark Davids and Robert F. Neff. *Physics: Principles and Problems*. Canadian edition. Toronto, ON: Maxwell Macmillan Canada Inc., 1992.

ISBN 0029541255

Basic learning resources for the 1976 Physics 30 program, as listed in the Learning Resources Distributing Centre *Buyers Guide*, are to be withdrawn August 31, 1994.

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